ARIZONA DEPARTMENT OF TRANSPORTATION
REPORT NUMBER FHWA/AZ 82/175

FIELD AND LABORATORY EVALUATION OF SULFUR ASPHALT PATCHING MATERIALS

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August, 1982

Prepared for:
Arizona Department of Transportation
206 South 17th Avenue
Phoenix, Arizona 85007
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16. Abstract

Patching deteriorated pavement is an important maintenance function. Presently used procedures and materials for patching are not always effective due to adverse weather, materials used, and procedures. Sulfur Asphalt Sand (SAS) materials have the potential for producing superior patches since they are pourable, require no compaction, and are highly stable.

SAS patching materials were developed in the laboratory using marginal aggregate sources and sulfur. Field trials using the Mini Cycle and the SAS patching materials were not satisfactory because of high SO_2 (greater than 50 ppm) emissions. The Mini Cycle will not be used to place any SAS patches but it was effective in placing recycled asphalt patches.

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INTRODUCTION

Patching deteriorated pavement is an important maintenance function. Proper patching extends the life of the pavement and improves the riding quality for the motoring public. A very expensive (labor intensive) and dangerous undertaking when under traffic, it is often not an effective procedure when improperly performed. Patches are frequently placed under adverse conditions (cold, damp, and in haste) and often not with the best materials; and because of this, they historically last only short periods of time.

There are three conventional patching techniques: 1) hot mixed, hot laid; 2) hot mixed, cold laid; and 3) cold mixed, cold laid. All of these are aggregate-asphalt mixtures with the last two containing some diluent in the asphalt. In Arizona, maintenance forces use cutback asphalt as the binder in their patching materials. These materials maintain their workability and do not have to be reheated during placement. Unfortunately, if placed under adverse weather conditions, distillates do not evaporate, the patch does not stabilize and is removed by traffic. To help with workability and compactibility, the gradation of the patch material is opened up to make it less dense. This allows water intrusion which further speeds up deterioration of the patch.

Another problem with the patching process is placement and compaction of material. Maintenance forces are usually attempting to maintain traffic around the work area and do not take the time to adequately prepare the pothole. Material is shoveled into the hole and a minimal amount of compaction applied. Ideally, the pothole should be cleaned out back to good dry material, tacked, and the patching material placed in layers and compacted.

Alternate binders may be required in the future because of environmental problems with cutbacks. One possible alternative is a composition of sulfur, asphalt, and sand (SAS) developed in Canada which consists of: 6% asphalt, 14% sulfur, and 80% sand. These are rough proportions though a normal mix will be in this range. It is self compacting, pourable, and very stable and the potential exists to place a durable patching material under adverse conditions.

The objective of this study was to develop a sulfur asphalt patching material and the procedures for placing them in the field, then to evaluate the performance of patches placed with SAS material.

LABORATORY EVALUATION

Several different sources of aggregate were investigated to develop a patching material. The goal was to use a source that would not need further processing which would reduce costs. Due to the high allowable voids in the mineral aggregate (VMA), it would also be possible to use aggregate sources that can not be used as is in asphalt concrete production. There are large supplies of blow sands in Arizona that could potentially be incorporated in a SAS mix. Two sources were tested and the mix design results are shown in Tables 1 and 2.

Table 1. Paulden Pit

Sulfur %	12	12	12	12	14	14	15	15
Asphalt %	5	5	6	6	5	5	5.5	5.5
Marshall-Flow				8		10		9
Stability				1060		1331		988
Hveem Stability			28		23		27	
Voids	13.8	12.8	11.7	11.4	14.3	13.0	12.3	13.7
VMA	35.4	34.6	35.5	35.3	38.0	37.0	38.8	39.8
% Filled	61.0	63.0	67.0	67.6	63.4	64.9	71.5	62.7

Table 2. Pit #5723

Sulfur %	12	12	12	12
Asphalt %	5	5	6	6
Marshall Flow			9	
Stability			2310	
Hveem Stability				38
Voids	16.5	15.1	9.8	9.7
VMA	38.0	37.0	34.8	34.7
% Filled	56.6	59.2	71.8	72.0

The asphalt used was an AR2000 and the gradation of the aggregate is shown in Table 3 with Figure 1 being its grading curve.

Table 3. Aggregate Gradation (% Passing)

Sieve Size	Paulden Pit	Pit #5723
3/8	100	100
1/4	86	91
4	80	86
8	64	77
10	59	76
16	43	73
30	23	70
40	18	53
50	14	38
100	9	18
200	7	8

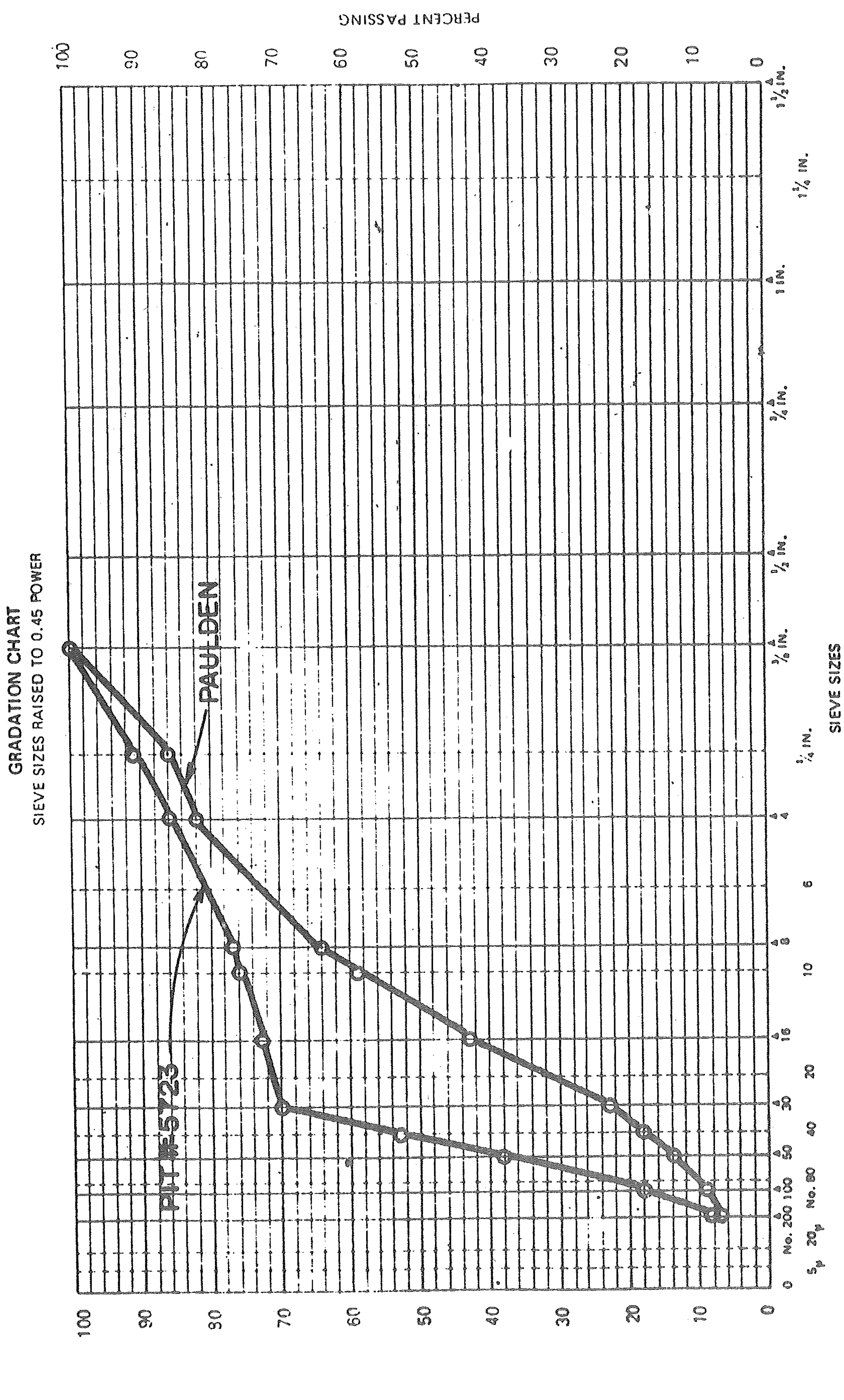

Figure 1. Aggregate Gradation

Specimens were not made in the normal manner. Materials were mixed at 275°F and poured into pre-heated compaction molds, rodded 25 times with a heated spatula and the top was troweled level. No other compaction was applied.

A problem associated with many Arizona aggregates and especially important with patching materials is that of water susceptibility. Specimens were prepared as above and tested by the Immersion-Compression test procedure. The specimens for both pits contained 6% asphalt, 12% sulfur, and 82% aggregate. The results are documented in Table 4.

Table 4. Immersion-Compression Results

	Air psi	Water psi	Retention %
Paulden Pit	148	76	51
Pit #5723	250	55	22

The results indicate Pit #5723 is highly water susceptible and for this reason, the Paulden Pit material was chosen for the field test.

FIELD EVALUATION

There were two objectives to this study. To develop a pourable, self-compacting and durable patching material and develop procedures to place this material in the field. From our work and that of others, it was apparent a material could be developed that might incorporate aggregate sources we are not presently able to use.

The second problem was more complicated. Sulfur asphalt sand must be placed at temperatures above 265°F, so a means of heating and keeping the material warm in the field was needed. A small asphalt recycling plant (Mini Cycle - Appendix A) was a potential solution. The plant is highly mobile, can heat the material to the required temperatures, and keep it warm. One major problem associated with all sulfur technology dealing with emissions did exist. In the plant, sulfur is exposed to direct flame if it is introduced during aggregate heat up. This would cause the evolution of sulfur dioxide (SO_2) which could be hazardous if produced in sufficient quantities (greater than 10ppm). Also hydrogen sulfide (H_2S) would be produced if the temperature of the mix rose above 310°F. The following procedures were used in an attempt to avoid emission problems:

1. Clean the drum by running virgin aggregate through it and heating (approximately 300°F).
2. Place aggregate in drum.
3. Heat aggregate to 275°F.
4. Turn off the flame.
5. Add the sulfur and asphalt.
6. Mix and empty drum.
7. Repeat the cycle.

This procedure did not produce the desired results. The second cleaning of the drum, now with sulfur asphalt coating it, produced high SO_2 emissions (greater than 50 ppm) all around the drum. Emissions of both SO_2 and H_2S were continuously monitored during this operation with an Interscan SO_2 gauge and an Ecolyzer H_2S gauge. During the rest of the production low levels of both gases were recorded and the SAS mix produced was thoroughly mixed and well coated. The problem though of SO_2 production during clean out makes this approach unacceptable.

Several other approaches were considered but all required more equipment and personnel. The concept of SAS patching materials has potential but is being put aside until new equipment is developed.

RECYCLED PATCHING MATERIALS

As a part of this study, the Mini Cycle was initially used to patch pavements with recycled materials. This was done to familiarize the crew with the operation of the equipment and determine if any modifications needed to be made. When it was found the Mini Cycle could not be used for sulfur asphalt patching, more work was done with it using recycled materials.

Results of the work in both ADOT's Districts 5 and 7 indicate a superior patch can be placed using the Mini Cycle and recycled materials. Work in District 5 was accomplished during the winter when normal patches are destroyed in several days, patches placed with the Mini Cycle were in excellent shape after two weeks in service. The operation in District 7 was more successful. They experimented with several materials, temperatures and varied the operation of the equipment. Results indicate these patches will not need any repair.

There are several reasons for success with recycled patches. First, material was hot when placed and care was taken to compact it and properly prepare the pothole before patching. The size of the crew used and the equipment was thought to be an economic problem by District 5 though District 7 showed the hot recycled patching operation to be less expensive. When longevity of the patches is taken into account with the reduced danger to the crew and improvement due to less traffic disruption; this appears to be a better procedure. More information on the actual operation appears in reference 14.

CONCLUSIONS

1. Pourable, self-compacting sulfur asphalt mixtures can be developed using marginal aggregate sources.

2. The Mini Cycle can not be used to make sulfur asphalt patches alone without producing unacceptable levels of SO_2 emissions.

3. Recycled materials can be used to produce superior patches with the Mini Cycle.

APPENDIX

General Specifications - Mini Cycle Plant

Mixing and Heating Chamber

Size	- 36" diameter x 48" long with 17" cone
Capacity	- 3 to 8 t.p.h.
Construction	- electrically welded all steel
Drum & Cone	- 3/16m steel
Insulation	- R 113-3 1/2" fiberglass compressed to 1"
Skin	- .051 aluminum
Mixer	- 8 flites 3/4" angle iron tangently placed
Tumbler	- 61 1/2" x 3" studs
Port	- 17" combination lump feed, heat inlet, and exhaust port

Feed (Sized Material)

Hopper	- 3 cubic feet
Feed	- 8" screw feeder 2 to 8 t.p.h.

Burner

Fuel	- 750,000 BTU, propane
Size	- 6" naturally aspirated 2" venturi

Drive

Gas engine with manual clutch
6:1 gear reducer with V-belt drive
H.D. machined pulleys "B" Section 2 groove with counter shaft
H.D. sprockets with No. 80 chain drive
4 heavy-duty roller bearing trunnions

Frame and Towing Tongue

Electrically welded 2x3x1/8 and 3x3x1/8 box tubing

Wheels and Suspension

15" wheels	- with 4 ply rated pneumatic tires
Fenders	- 14 ga. steel
Axle	- 2x2-3/16 box tubing
Springs	- 1400 lbs. spring leaf

Engine House

14 ga. steel with engine throttle, off/on switch and clutch control

Towing Empty Weight

Axle	- 1150 lbs.
Frame	- 200 lbs.
Total	- 1350 lbs.

Dimensions

Overall width	- 56"
Overall height	- 63"
Overall length	- 143"

Power Unit

Model EY27W Wisconsin Robin Engine air cooled, 7 1/2 HP single cylinder 4 cycle 16.26 cubic inch, H.D. cast iron liner, forged steel crank shaft, ball main bearings both ends, bore 2.91" stroke 2.44", 1.45 gallon fuel tank, 1.6 pint oil capacity. This power is subject to availability and may be substituted.

REFERENCES

1. Burgess, R. A., I. Deme, "The Development of the Use of Sulphur Asphalt Paving Mixes", Adv. Chem. Ser. (1974) 140,85.

2. Burgess, R. A., I. Deme, "Sulfur in Asphalt Paving Mixes", Advances in Chemistry Series #140, New Uses of Sulfur, 1975.

3. Deme, I., "Basic Properties of Sand-Asphalt-Sulphur Mixes", prepared for presentation at the VII International Road Federation World Meeting, Munich, West Germany, October, 1973.

4. Deme, I., "Processing of Sand-Asphalt-Sulphur Mixes", Proc. AAPT Vol. 43, 1975.

5. Deme, I., "Sulfur as an Asphalt Diluent and a Mix Filler", Advances in Chemistry Series No. 165, ACS, 1978.

6. Deme, I., "The Use of Sulphur in Asphalt Paving Mixes", paper prepared for Fourth Joint Chemical Engineering Conference, Vancouver, British Columbia, September, 1973.

7. Epps, J. A., C. L. Monismith, "Fatigue of Asphaltic Concrete Mixtures - Summary of Existing Information", Fatigue of Compaction Bituminous Aggregate Mixtures, ASTM STP 508, ASTM, 1972, pp. 19-45.

8. Gallaway, R. W., D. Saylack, "Sulphur Extended Asphalt (SEA)", FHWA-TS-78-203, January, 1976, Reprint 1977.

9. Garrigues, C., P. Vincent, "New Uses of Sulfur", Advances in Chemistry Series 140, Amer. Chem. Soc., 1974, p. 130.

10. Glascock, L. A., "A Laboratory Evaluation of Sulphur-Asphalt Paving Mixtures", Research Report 100, Louisiana Department of Highways, February, 1976.

11. Haas, R., "A Method for Designing Asphalt Pavements to Minimize Low Temperature Shrinkage Cracking", Asphalt Institute Research Report 73-1, January, 1973.

12. Hammond, R., I. Deme, D. McManus, "The Use of Sand-Asphalt-Sulphur Mixes for Road and Surface Applications", prepared for annual meeting of the Canadian Technical Asphalt Association, Montreal, November 1971.

13. Hignell, E. T., J. J. Hajek, R. C. G. Haas, "Modification of Temperature Susceptibilities of Asphalt paving Mixtures", AAPT Vol. 41, 1972.

14. Hounshell, C., "Patching with Recycled Material Produced in the Mini Cycle", ADOT, September, 1982.

15. Irvin, L. H., B. M. Gallaway, "Influence of Laboratory Test Method on Fatigue Test Results for Asphalt Concretes", Fatigue and Dynamic Testing of Bituminous Mixtures, ASTM STP 561, ASTM 1974, pp. 12-46.

16. Izatt, J. O., B. M. Gallaway, D. Saylak, "Sand-Asphalt Sulphur Pavement Field Trial, Highway U.S. 77, Kennedy County, Texas, A Construction Report", FHWA-TS-78-20A, April, 1977.

17. Izatt, J. O., B. M. Gallaway, D. Saylak, "Sand-Asphalt-Sulphur Pavement Field Trial Highway U.S. 77, Kennedy County, Texas, Texas Transportation Institute, April, 1977.

18. Izatt, J. O., "Sulphur-Asphalt Binder Pavement Test U.S. 69-Lufkin, Texas, A Construction Report", The Sulphur Institute, September, 1975.

19. Izatt, J. W., "Sulphur-Asphalt Sand Paving Project, Highway LA 108 Sulphur Louisiana - A Construction Report", The Sulphur Institute, January, 1977.

20. Izatt, J. O., "Sulphur Extended Asphalt Paving Project, Highway U.S. 93-95 Boulder City, Nevada - A Construction Report", The Sulphur Institute, January, 1977.

21. Kennedy, T. W., et al, "An Engineering Evaluation of Sulphur-Asphalt Mixtures", TRB Record, 1977 in press.

22. Kennepohl, G. J. A., A. Logan, D. C. Bean, "Conventional Paving Mixes with Sulphur-Asphalt Binders", Proc. AAPT Vol. 44, 1975.

23. Kennepohl, G. J., L. J. Miller, "Sulphur-Asphalt Binder Technology for Pavements", prepared for American Chemical Society Meeting, New Orleans, LA, March, 1977.

24. Kennepohl, G. J. A., A. Logan, D. C. Bean, "Sulphur-Asphalt Binders in Paving Mixes", Can. Sulphur Symp. (pcp.) (1974).

25. Lee, D. Y., "Modification of Asphalt and Asphalt Paving Mixtures by Sulphur Additives", Ind. Eng. Chem., Prod. Res. Dev. (1975) 14 (3).

26. Lytton, R. L., D. Saylak, D. E. Pickett, "Prediction of Sulphur-Asphalt Pavement Performance with VESYS II M", Fourth International Conference Structural Design on Asphalt Pavements, Vol. 1 Proceedings, August, 1977.

27. McBee, W. C., T. A. Sullivan, "Direct Substitution of Sulfur for Asphalt in Paving Materials", U. S. Bureau of Mines.

28. McBee, W. C., T. A. Sullivan, "Improved Resistance of Sulfur Asphalt Paving to Attach by Fuels", IEC Prod. Res. Dev. (March 1977 22 (1).

29. McBee, W. C., T. A. Sullivan, D. Saylak, "Recycling Old Asphaltic Pavements with Sulfur", prepared for the American Society for Testing and Materials Symposium on Recycled Materials (no date).

30. McBee, W. C., D. Saylak, T. A. Sullivan, R. W. Burnett, "Sulfur as a Partial Replacement for Asphalt in Bituminous Paving", New Horizons in Construction Materials, Envo. Publishing Company, Lehigh Valley, Pennsylvania, 1976, po. 345-362.

31. McBee, W. C., T. A. Sullivan, "Sulfur Utilization in Asphalt Paving Materials", Advances in Chemistry Series, No. 165, ACS. 1978.

32. McBee, W. C., T. A. Sullivan, "Utilization of Secondary Sulfur in Construction Materials", Proceedings of the Fifth Mineral Waste Utilization Symposium, U.S. Bureau of Mines and IIT Research Institute, 1976, pp. 39-52.

33. Meyer, F. R. P., E. T. Hignell, G. J. A. Kennepohl, R. C. G. Haas, "Temperature Ssuceptibility Evaluation of Sulphur-Asphalt Mixtures", Proceedings AAPT Vol. 46, February, 1977.

34. Pronk, F. E., et al, "Sulphur Modified Asphaltic Concrete", Proc. Can. Tech. Asphalt Assoc. (1975) XX.

35. Saylak, D., B. M. Gallaway, "The Use of Sulphur in Sulfur Asphalt Aggregate Mixes", Interim Conf. Mater. Technol. 4th (July 1975).

36. Schmidt, R. J., "A Practical Method for Determining the Resilient Modulus of Asphalt Treated Mixes", HRR 404, 1972.

37. Shane, G., R. A. Burgess, "The Thermopave Process" prepared for presentation at the Sulphur Institute Symposium on New Uses for Sulphur, Madrid, May 17-19, 1976.

38. Sullivan, T. A., W. C. McBee, K. L. Rasmussen, "Studies of Sand-Sulfur-Asphalt Paving Materials", U.S. Bureau of Mines Rep. Invest. (1975) 8087.

39. "Beneficial Uses of Sulphur in Sulphur-Asphalt Pavements Final Report, Vol. I, II, III, and Final Report 7-1-76 to 11-1-77", Texas A&M Research Project RF 983-1B, August 1974.